Water Treatment Feasibility Study
GROUNDWATER PUMP-OUT SYSTEM

GENERAL MILLS EAST HENNEPIN AVENUE SITE

Prepared for GENERAL MILLS, INC. August 1984

By BARR ENGINEERING CO. Minneapolis, MN

FEASIBILITY OF TREATING GROUNDWATER REMOVED BY PUMP-OUT WELLS

GENERAL MILLS EAST HENNEPIN AVENUE SITE

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I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

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Date: 8/13/84

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FEASIBILITY OF TREATING GROUNDWATER REMOVED BY PUMP-OUT WELLS
GENERAL MILLS EAST HENNEPIN AVENUE SITE

INTRODUCTION

A groundwater pump-out system will be used as part of the plan to minimize the migration of volatile organic solvents from a former solvent adsorption pit located at the former General Mills, Inc. property at 2010 East Hennepin Avenue. The groundwater pump-out system will include five wells finished in the glacial drift aquifer and one well finished in the Carimona Member of the Platteville Formation.

The specific requirements of the pump-out system will be agreed upon by the regulatory agencies and General Mills, Inc. in an administrative order that is currently being prepared. Since the storm sewer is the most cost-effective discharge location for the water removed by the pump-out system, the Minnesota Pollution Control Agency (MPCA) required that General Mills, Inc. investigate the technical feasibility and cost of treating the discharge from the three pump-out wells that are in the most concentrated portion of the solvent plume. The specific requirements of the feasibility study are described in Section 1.3 of Part I of Exhibit A to the draft Administrative Order dated June 29, 1984 prepared by the MPCA.

This report summarizes the results from the feasibility study required by Section 1.3 of Part I of Appendix A to the draft Administrative Order. As described in the Order, the purpose of the feasibility study is to help define the best available technology economically achievable for treating the groundwater removed by the three wells in the most contaminated part of the plume and to help define effluent limitations for the discharge from a treatment system to the storm sewer system.

The location of the former solvent adsorption pit and the locations of the pump-out wells are shown in Figure 1. Well 108 is a 6-inch diameter well finished in the Carimona Member of the Platteville Formation. Well 109 is a 10-inch diameter well finished in the glacial drift aquifer and is located immediately downgradient of the former absorption pit. Well 110, which will be constructed in the future, will be finished in the glacial drift aquifer and located on public right-of-way approximately 900 feet downgradient of the former absorption pit. At the present time, it is anticipated that Well 110 will be located on the south side of Como Avenue about mid-block between 19th and 20th Avenues. Wells 111, 112 and 113, which will also be constructed in the future, will be finished in the glacial drift aquifer and located on public right-of-way. These three wells will be located approximately 2,300 feet downgradient of the former pit near the intersections of Rollins Avenue and 15th, 17th and 18th Avenues, respectively.

The discharges from Wells 108, 109 and 110 were included in this investigation of technical feasibility and treatment cost since these wells are located close to the former absorption pit and the discharges will have the highest concentrations of solvents. Wells 111, 112 and 113 were not included since the solvent concentrations in the discharges from these wells will be lower and the direct discharge of the water from these wells to the storm sewer was considered acceptable.

This report summarizes the treatment options that were considered for the water from Wells 108, 109 and 110, the assumptions used in the study, the results from an air stripping pilot test conducted using water from Well 109, preliminary designs of several treatment and piping options, a cost analysis, and recommendations for effluent limitations to be included in a NPDES permit for the discharge from a treatment facility.

APPROACH

The feasibility study described in the draft Order includes assessing the cost and feasibility of treating the discharges from the three most contam inated pump-out wells in the system by carbon adsorption and air stripping. Conceptual designs and cost estimates were prepared for treating water from three pump-out well options. The pump-out options examined in this study are:

- Option A -- Treatment of water from Well 109 only, with other wells discharging directly to the storm sewer

- Option B -- Treatment of the water from Wells 108 and 109, with the other wells discharging directly to the storm sewer

- Option C -- Treatment of water from Wells 108, 109 and 110, with the remaining wells discharging directly to the storm sewer.

For each of these options, the technical feasibility and cost of providing three levels of treatment by air stripping (90 percent, 95 percent and 99 percent removals) and the technical feasibility and cost of providing treatment by carbon adsorption were evaluated.

GENERAL ASSUMPTIONS

A number of general assumptions were used as the basis for the conceptual designs and cost estimates of the various treatment and pump-out well options. These include the quality of the groundwater that will initially be removed from the various wells, the expected rate of discharge from each well, the design life of the equipment, applicable treatment equipment (in the case of carbon adsorption), and the locations of the treatment facility and storm sewer discharges. The general assumptions used in the investigation are described in the following paragraphs:

1. Quality of Groundwater Removed from Each Well -- The quality of the groundwater initially removed from each of the three wells included in the investigation was based on samples collected from the existing pump-out wells (in the case of Wells 108 and 109) and on the data collected from monitoring wells in the general vicinity of the future wells (in the case of Well 110). A summary of the expected quality of water that will be removed from Wells 108, 109 and 110 is shown in Table 1. Wells 108 and 109 are located in the zone of highest groundwater solvent concentrations in the Carimona member of the Platteville and the shallow drift aquifers, respectively. The concentrations of solvents in the discharge from future pump-out wells was assumed to be less than the concentrations in samples from adjacent monitoring wells because the pump-out wells are screened over the entire depth of the glacial drift aquifer (15 to

25 feet) while the monitoring wells are screened only in the upper 4 to 7 feet of the saturated zone.

2. Well Discharge Rate -- The design flow rate for the treatment facility was assumed to be 75 gallons per minute (gpm) per well, even though the actual yield from each well will likely average closer to 50 gpm over the long-term.

3. Design Life -- The pump-out system will likely operate for at least 5 years and possibly for much longer. Because of the expected long operating life, the selected treatment technology must be dependable and have a relatively low operating and maintenance cost to be cost-effective.

4. Treatment Facility Location -- The area underlain by the solvent plume contains residential and commercial development. The only reasonable location for the treatment facility is on the former General Mills property, located adjacent to the absorption pit near 21st Avenue and Talmage Avenue S.E. Water would be pumped through a buried forcemain from each pump-out well to the treatment facility.

5. Discharge from Pump-Out Wells and Treatment Facility -- It is planned that the discharge from the pump-out wells and treatment facility will be pumped to the Como Avenue deep tunnel storm sewer system. The discharges from the individual wells will enter the storm sewer at different locations along the route of the sewer. The shallow storm sewer laterals are connected to the deep tunnel by vertical drop shafts that are approximately 100 feet in length. The deep tunnel storm sewer is approximately 6,000 feet in length and extends from the vicinity of 18th and Hennepin Avenues to the Mississippi River, east of the 10th Avenue bridge.

TREATMENT TECHNOLOGIES

The air stripping and carbon adsorption technologies used to develop the conceptual designs and resulting cost estimates are described in the following paragraphs.

Air Stripping

Water from the pump-out well(s) that will be treated by air stripping will be pumped to the top of the stripping tower. The water will then flow downward by gravity through the tower packing material as air is forced up through the packing material by a blower. The packing material is designed to cause an efficient mixing of the air and water resulting in the volatile organic solvents being transferred from the water to the air. The major design factors which control the transfer of the solvents from the water to the air are the height of the packing material in the tower, the tower diameter, and the air-to-water ratio.

A pilot-scale air stripping study was used to obtain data for sizing an air stripping treatment facility to remove 90 percent, 95 percent, and 99 percent of the volatile organic solvents from the groundwater pumped from the various pump-out wells. The methods and results from the pilot-scale study are presented in Appendix A to this report (Air Stripping Pilot Study Report - Recovery Well, Hennepin Avenue Site, Minneapolis, Minnesota, July 20, 1984, K.M. Sullivan, Hydro Group, Environmental Products Division). The most significant conclusion from the pilot-scale study is that it is technically feasible to use air stripping to remove as much as 99 percent of the solvents from the most highly contaminated well in the pump-out well system (Well 109). The design criteria obtained from the pilot-scale study for the treatment of water from Well 109 at three flow rates (75, 150 and 225 gpm) and three levels of treatment (90, 95 and 99 percent removal) are shown in Table 2.

Carbon Adsorption

The design of the carbon adsorption treatment facility was based on using multiple pressure carbon contactor units containing granular activated carbon with a surface loading rate of 3 to 6 gpm per square foot and a hydraulic detention time of 15 minutes. The level of solvent removal from the pump-out wells by the carbon adsorption units can reasonably be assumed to be at least 99 percent. The facility was designed so a spent carbon contactor could be removed from service after breakthrough without shutting down the treatment system. After breakthrough, it was assumed that the spent activated carbon would be replaced with fresh carbon, with regeneration of the spent carbon provided off-site. The inflow to the carbon contactor units was assumed to be pre-treated by polyphosphate addition to reduce the accumulation of iron precipitate on the carbon and to be periodically chlorinated to minimize the build-up of algae on the carbon. The contactor units were also assumed to require periodic backwashing to reduce pressure loss through the system. The design criteria used for the carbon contactors are shown in Table 2.

CONCEPTUAL DESIGNS AND COSTS

Conceptual designs were completed and costs were estimated for the three pump-out well options (Options A, B and C) described earlier. Under Option A, water from the on-site glacial drift pump-out well (Well 109) will be treated prior to discharge to the storm sewer, while water from the other pump-out wells will be discharged directly to the storm sewer. Under Option B, water from the on-site glacial drift pump-out well and the on-site Carimona well (Well 108) will be treated prior to discharge, while water from the other pump-out wells will be discharged directly to the storm sewer. Under Option C, water from Well 108, Well 109, and the future glacial drift pump-out well on Como Avenue (Well 110) will be treated prior to discharge, while water from the other pump-out wells will be discharged directly to the storm sewer.

Conceptual designs and cost estimates were based on a single tower air stripping unit designed to remove 90 percent, 95 percent and 99 percent of the volatile organic solvents in the water from the various pump-out wells. The designs and costs for the air stripping facility are based on the pilot-scale study described previously and on other available data. Conceptual designs and cost estimates were also prepared for treating the water from the wells in the three pump-out well options using carbon adsorption. The estimated capital and annual operating and maintenance costs for the each pump-out well option using each treatment technology and each level of removal are summarized in Table 3. Detailed cost estimates are included in Appendix B.

In addition to monitoring the wells in the pump-out well system, Appendix A to the draft Order requires the monitoring of 37 wells six times per year. The estimated cost for this monitoring, including sampling, sample analysis and report preparation is $100,000 per year. This cost is in addition to the costs included in the tables and figures in this report.

The capital cost of the pump-out well and treatment facility were divided into the following five categories:

- Treatment
- Wells 108, 109, 110 and Appurtenances
- Well 108, 109 and 110 Discharge Piping
- Wells 111, 112, 113 and Appurtenances
- Well 111, 112 and 113 Discharge Piping.

Annual operating and maintenance costs were divided into:

- Treatment
- Pumping
- Monitoring.

The conceptual designs and resulting cost estimates for each pump-out well option are described below.

Option A -- Treat Water From Well 109

With Option A, water from Well 109 will be pumped to the treatment facility located northwest of Well 109. The treated water will be discharged from the treatment facility to the lateral storm sewer system at the intersection of 21st and Talmage Avenues. Water from Well 108, also located onsite, will be discharged directly to the storm sewer at the same location and water from Well 110 will be discharged directly to the storm sewer at the intersection of 20th Avenue and Como Avenue. Water from Wells 111, 112 and 113 was assumed to be discharged directly to the storm sewer at the intersection of 18th Avenue and Elm Street under all options.

Water from Well 109 will be pumped through a forcemain to the treatment facility. To protect against freezing, the forcemain was assumed to have 7½ feet of cover. To accommodate a buried discharge pipe, the well head for Well

109 will be fitted with a pitless unit. It was assumed that the forcemain will be constructed of polyethylene pipe and installed from the surface in an open trench with approximately ½:1 side slopes. In pavement areas, it was assumed that the peat will be removed and replaced with granular fill.

The water from Well 109 will be discharged into the top of the air stripping tower or the pressure flow carbon contactor. The tower will be from 15 to 24 feet in height with the final height depending on the percent removal of the volatile organic solvents that will be used as the basis for the design. The base of the tower will be housed in a concrete block building. If carbon adsorption is used, the carbon adsorption contactors will be housed in a building slightly larger than the building needed for an air stripping facility. The building at the treatment facility will contain the controls for the treatment facility and for Well 109. The building will also reduce noise from the blower of an air stripper.

After passing through the treatment facility, the water will be discharged through a new gravity flow pipeline to the catch basin at the intersection of 21st and Talmage Avenues. Rebuilding of the catch basin and some street restoration will be required.

Under Option A, water from Well 108 which is the on-site Carimona well, will be discharged directly to the storm sewer. To meet Minnesota Department of Health requirements, an air break will be constructed either at the well head or at the discharge point for each well not connected to the treatment facilty. The air break will prevent stormwater from entering the well during times of flooding in the storm sewer or street. After the air break, the water from Well 108 will flow directly into a manhole and through a gravity flow pipeline to the catch basin at the intersection of 21st and Talmage Avenues.

Under Option A, water from Well 110 will also be discharged directly to the storm sewer. To maintain 7½ feet of cover on the forcemain from Well 110 to the storm sewer, a pitless unit will be fitted on the Well 110 well head. Water from Well 110 will be pumped through the forcemain to a manhole near the intersection of 20th Avenue and Como Avenue. An air break will be constructed at the manhole. From the air break, the water will be discharged into a manhole and through a new gravity pipeline to an existing 12-inch diameter vertical drop shaft to the deep storm tunnel at the intersection of 20th Avenue and Como Avenue.

Water from Wells 111, 112 and 113 will be pumped through a forcemain along Rollins Avenue to 18th Avenue, then south on 18th Avenue to an existing storm tunnel drop shaft at the intersection of 18th Avenue and Elm Street. Wells 111, 112 and 113 will also be fitted with pitless units so that 7½ feet of cover can be maintained over the forcemain.

A manhole containing a flow meter, gate valve, check valve, and a sampling hydrant will be provided at each well in the system. As a safety feature, automatic switches will be installed on the pumps for Wells 108, 109 and 110 to shut the pumps off at a certain drawdown level and to turn the pumps on as the water level recovers.

The major capital cost for an air stripping facility is the air stripping unit. The major capital cost for a carbon adsorption facility is the carbon contactor units. The cost of each treatment facility includes an electrical service hookup, controls for the automatic shutoff of the system, and a building to house the facility. The pipeline from the treatment facility to the storm sewer is also included in the cost of the treatment facility. Mobilization includes the cost of obtaining building permits and insurance, moving equipment, and administrative activities.

Although Wells 108 and 109 have been constructed, the installation cost of these wells is included in the cost estimates to illustrate the cost of the complete pump-out system. The cost of providing power to Wells 108 and 110 is included in the "Wells 108, 109, 110 and Appurtenances" category. The cost of providing power to Well 109 was included in the cost of the treatment facility.

Included in the "Wells 108, 109 and 110 Discharge Piping" category are the forcemain from Well 109 to the air stripping unit, the forcemain from Well 110 to the air break, the gravity pipeline from Well 108 to the storm sewer and the gravity pipeline from the Well 110 air break to the storm tunnel drop shaft. The forcemains and gravity pipelines were assumed to be constructed beneath the street since existing utilities make placement in the boulevard impractical. The removal and subsequent replacement of the street pavement are significant costs associated with the pipelines. The City of Minneapolis requires that any peat soil underlying the pavement be removed and replaced with granular soil, prior to pavement replacement. The City of Minneapolis also requires that the City pave the streets after construction. The unit price for street replacement used in the cost estimate ($50 per square yard) was obtained from the City.

Included in the "Wells, 111, 112, 113 and Appurtenances" category are costs for well installation, pumps, pitless units and a manhole, controls and electrical service to each well.

The assumptions used to estimate the costs in the "Well 111, 112 and 113 Discharge Piping" category were similar to the assumptions used to estimate the cost of the Well 110 discharge piping. Peat soils will be removed and granular material will be used to backfill the trench.

For purposes of the cost estimate, engineering and administrative costs were assumed to total 15 percent of the capital cost and a contingency reserve equal to 20 percent of the capital cost was included. Table 3 summarizes the Option A costs and more detailed costs are provided in Appendix B.

Operating and maintenance costs for the air stripping facility include electricity, maintenance, and replacement costs for the blower. The maintenance and replacement costs were assumed to be 15 percent of the original cost of all equipment. Monitoring the performance of the treatment facility (manpower and testing) is also included in the operating and maintenance cost. Five man-hours per week were assumed to be sufficient to operate and maintain the air stripping facility. The cost of treatment facility performance monitoring was based on the assumption that each pump-out well would be sampled six times per year, that the treatment facility effluent would be sampled two times per month, and that monthly data reports and an annual survey report would be prepared. The monitoring cost shown in Table 3 does not include the cost of monitoring the numerous monitoring wells that are included in the draft Order. As discussed previously, the cost of monitoring the various monitoring wells included in the draft Order is estimated to be $100,000 per year.

Operating and maintenance costs for the carbon adsorption facility include operation of the pre-treatment facility, backwashing of the contactors, equipment monitoring and spent carbon replacement. Twenty man-hours per week were assumed to be required to operate and maintain the carbon adsorption facility. This greater time reflects the more complicated nature of the carbon adsorption facility in comparison to the air stripping facility.

Pumping costs were based on a 3 horsepower motor in each of the six wells. It was assumed that well discharge will be regulated by throttling the discharges with gate valves. Maintenance and replacement costs for the pumps were assumed to be 15 percent of their original cost. The operating and maintenance costs for Option A are also shown in Table 3.

Option B -- Treat Water From Wells 108 and 109

As described previously, the Option B pump-out well system is similar to the Option A system except that water from Well 108 will be treated at the treatment facility under Option B and not discharged directly to the storm sewer. Instead of the gravity pipeline from Well 108 to the storm sewer, a forcemain will be constructed from Well 108 to the treatment facility and the flow rate through the treatment facility will increase from 75 gpm to 150 gpm.

The only change in the cost of the treatment facility for Option B is the cost required to accommodate the larger flow rate. The Option B costs included in the "Wells 108, 109, 110 and Appurtenances" category differ from those in Option A only by the cost of furnishing and installing a pitless unit on Well 108. The costs in the "Well 108, 109 and 110 Discharge Piping" category under Option B differ from those in Option A only by the cost of the additional forcemain. The costs for the Wells 111, 112, 113 and appurtenances and discharge piping categories do not change from those in Option A. The capital cost of Option B is summarized in Table 3 and more detail about the changes from the costs of Option A is provided in Appendix B.

The operating and maintenance costs for the air stripping facility under Option B increase slightly over those in Option A due to the additional electrical demand of the slightly larger blower motor. The maintenance and replacement costs for the air stripping facility and the equipment monitoring cost remains about the same as in Option A. The operating and maintenance cost for carbon adsorption under Option B increase over Option A because of increased carbon use. The maintenance and replacement cost for carbon adsorption treatment under Option B increase slightly over Option A based on a percentage of the capital cost. The operating and maintenance costs for Option B are also summarized in Table 3.

Option C -- Treat Water From Wells 108, 109 and 110

The Option C pump-out well system is similar to Option A except that the water from Wells 108 and 110 will be pumped to the treatment facility instead of discharged directly to the storm sewer.

The major changes in the system are a larger air stripper to accommodate the water from Wells 108 and 110 and the forcemains to carry the water from Wells 108 and 110 to the treatment facility. The treatment costs are slightly higher for Option C than for Option A because of the larger facilities required. It was assumed that the forcemain from Well 110 to the treatment facility will follow the alignment shown in Figure 1. Subsoil and utility conditions make an open trench necessary for installation of the forcemain. The capital and operating/maintenance costs for Option C are summarized in Table 3 and more detail about the differences in costs under Options C and A is provided in Appendix B.

CONCLUSIONS

The following conclusions are based on the results of this investigation:

1. Using either air stripping or carbon adsorption, it appears to be technically possible to remove a very high percentage (99 percent) of the solvents from the water from the most contaminated pump-out wells in the pump-out well system.

2. The graph showing the capital and annual costs versus the degree of removal (Figure 2) shows that air stripping is more cost-effective than carbon adsorption to remove the solvents at all removal efficiencies investigated.

3. The cost data in Table 3 show that there is no significant cost differences between air stripping facilities designed to achieve 90 percent, 95 percent and 99 percent removal of solvents.

4. The cost and removal efficiency data (Tables 3 and 4) show that the total annual cost to treat the water from pump-out Wells 108 and 109 (Option B) is only about 2 percent greater than the cost to treat the water from only Well 109 (Option A), although an additional 320 pounds of solvent per year (29 percent of the total anticipated to be discharged from the pump-out wells) will be removed from the storm sewer.

5. The cost and removal efficiency data show that the total annual cost of the treatment of the water from all three pump-out wells (Option C) is about 18 percent greater than the cost of treating the water from Wells 108 and 109, with the removal of an additional 180 pounds of solvent per year (16 percent of the total) from the storm sewer.

The fate of the volatile organic solvents after discharge to the storm sewer system is dependent on the rate of transfer of the volatile organics from the liquid phase to the vapor phase within the storm sewer. The fate of the volatile organic solvents in the storm sewer was assessed in January, 1984 during the test pumping of Well 108. During the test pumping, water from Well 108 was discharged to the 54-inch diameter storm sewer along Talmage Avenue. This sewer flows into the Como Avenue deep tunnel at the intersection of 18th and Talmage. Water samples collected at the outlet of the Como Avenue deep tunnel during the test pumping did not show the presence of chlorinated or non-chlorinated solvents above the reporting limits. Volatile organic vapors were measured in the catch basins along Talmage Avenue with a vapor analyzer during the time that water from Well 108 was being discharged to the storm sewer system. The vapor monitoring indicated that concentrations of volatile organics were detectable above background levels at only the two catch basins closest to the Well 108 discharge point. It is anticipated that most of the volatile organic solvents in water discharged to the storm sewer system will volatilize within 400 feet of the point of entry or within the vertical drop shaft to the deep tunnel.

RECOMMENDATIONS

1. The most cost-effective option is to treat the water from Wells 108 and 109 using an air stripping facility designed to remove 99 percent of the solvents. The water from the other four wells should be discharged directly to the storm sewer.

2. Because 99 percent removal of the solvents will produce an effluent that is near the lower limit of the concentrations that can be repeatedly monitored and because of the variables that will periodically reduce the operating efficiency of the air stripper below design criteria, the treatment facility should initially be expected to remove an average of 98 percent of the volatile organic compounds in the treatment facility inflow with a daily minimum removal of 95 percent.

3. Since the high percentages of removal anticipated above may be difficult to obtain (and will not be necessary) as the quality of the groundwater from the pump-out wells improves, the water treatment facility should be required to produce an effluent of 50 ug/L of trichloroethylene as an annual average with a daily maximum of 100 ug/L.

Figures

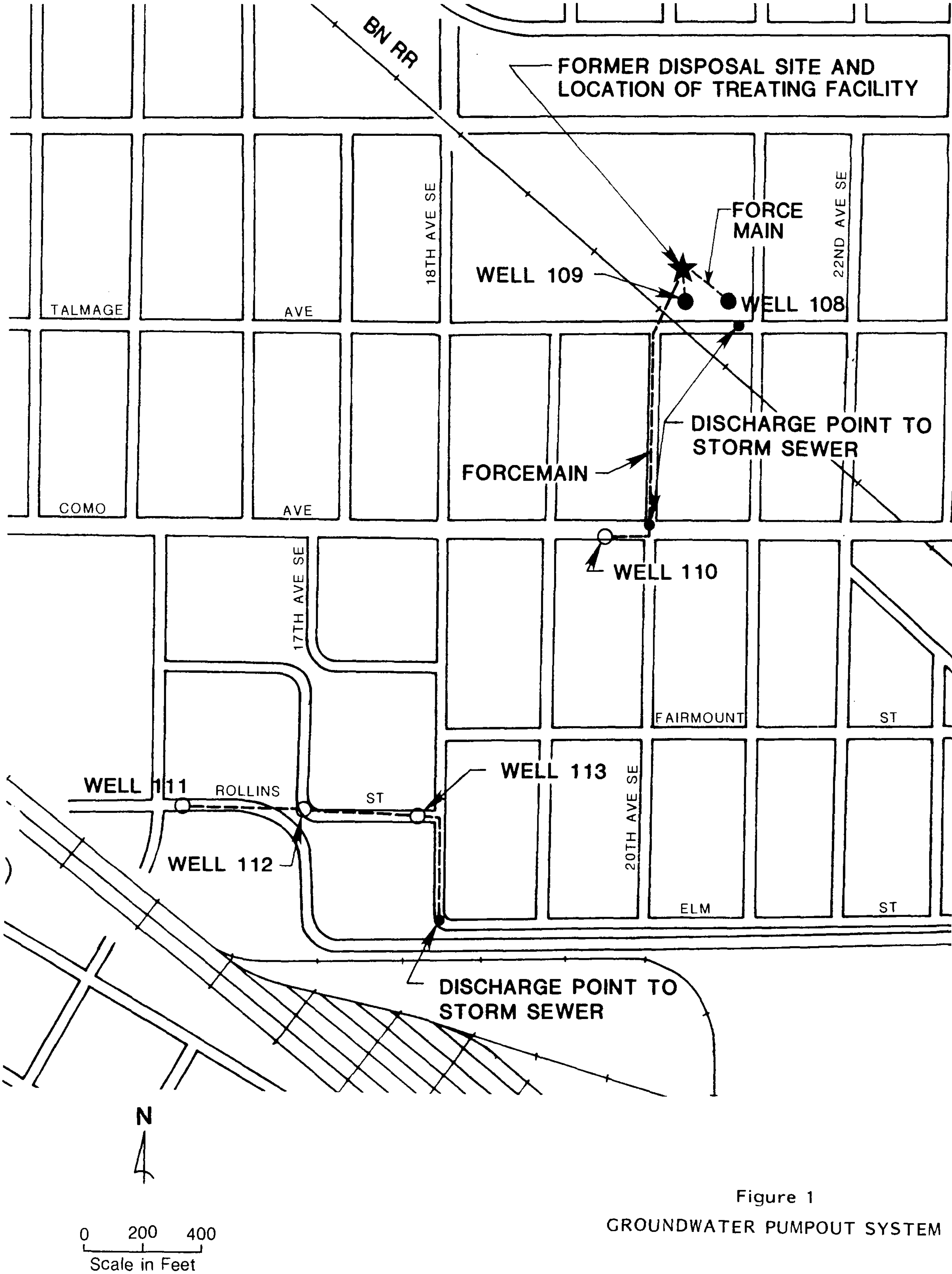

Figure 1
GROUNDWATER PUMPOUT SYSTEM

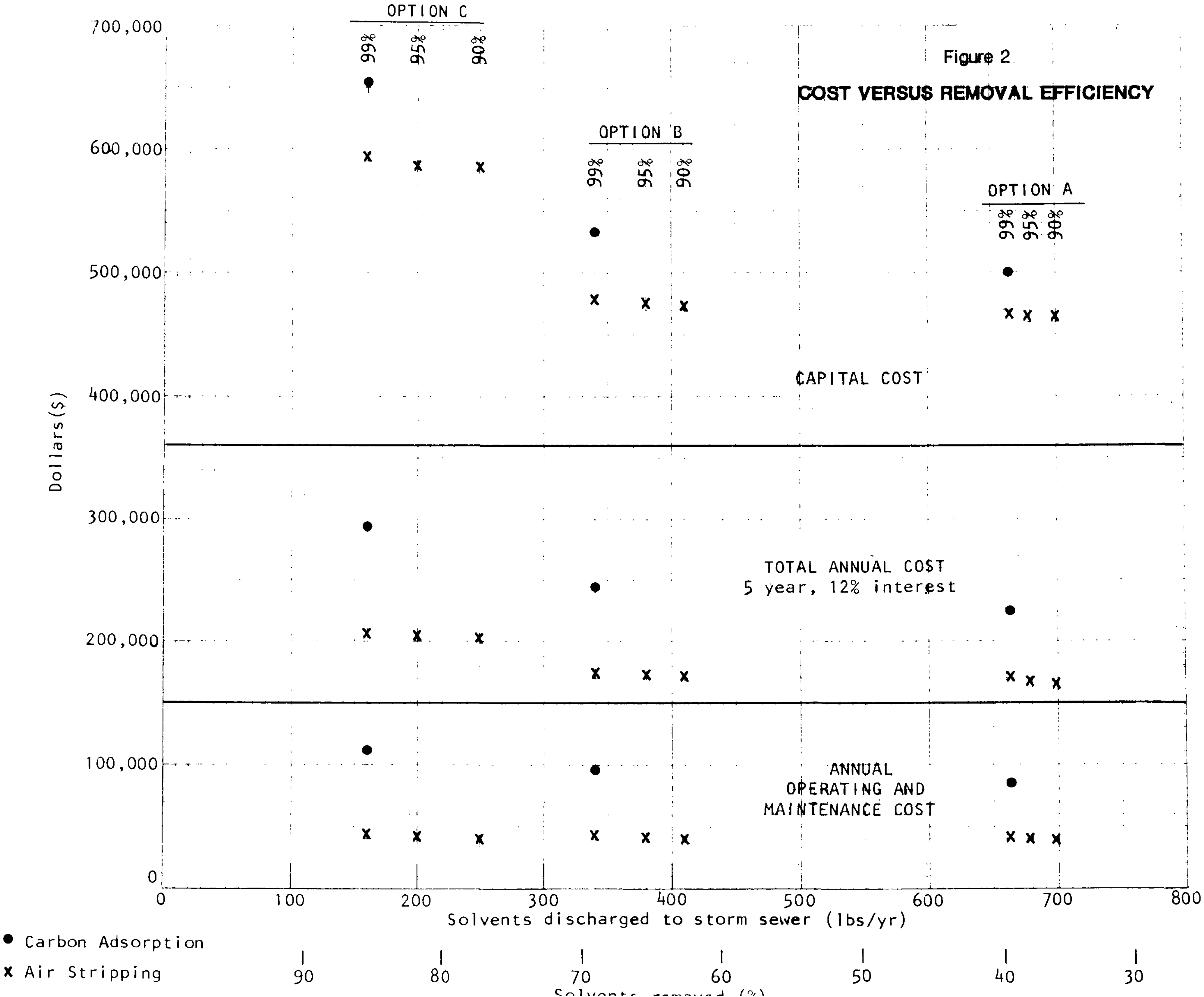

Figure 2
COST VERSUS REMOVAL EFFICIENCY

Tables

TABLE 1

ANTICIPATED QUALITY OF WATER INITIALLY REMOVED
FROM WELLS 108, 109 AND 110
(concentrations in μg/L)

	Well 109 Glacial Drift	Well 108 Carimona	Well 110 Glacial Drift[1]
1,1-Dichloroethane	13	7.0	2
1,2-Dichloroethane	30	0.2	--
1,1-Dichloroethylene	2.3	--	--
1,2-Dichloroethylene, total	130	220	130
Dichloromethane	<3.0	--	1
Tetrachloroethylene/ 1,1,2,2-Tetrachloroethane	29	9.0	18
1,1,1-Trichloroethane	130	10	3
Trichloroethylene	1,100	1,100	650
Trichloromethane	180	<0.1	--
Benzene	240	<5.6	--
Toluene	490	<1.6	--
Xylene	86	<1.6	--
Total of Volatile Organic Compounds	2,000	1,300	800

[1]Based on data from Monitoring Well J adjusted (divided by 2) to reflect penetration of well screen.

--means no data available.

TABLE 2

DESIGN CRITERIA FOR TREATMENT FACILITIES

	Pump-Out Well Option		
	A	B	C
	Q = 75 gpm	Q = 150 gpm	Q = 225 gpm
Air Stripping Unit			
% Removal	90	90	90
Diameter (ft)	3.0	3.5	4.0
Packing Height (ft.)	7	8	9
Overall Height (ft.)	15	16	17
Air:Water Ratio	150	150	125
Blower BHP	0.7	0.8	0.9
% Removal	95	95	95
Diameter (ft.)	3.0	3.5	4.0
Packing Height (ft.)	9	10	11
Overall Height (ft.)	17	18	19
Air:Water Ratio	150	150	125
Blower BHP	0.9	1	1.1
% Removal	99	99	99
Diameter (ft.)	3.0	3.5	4.0
Packing Height (ft.)	15	16	16
Overall Height (ft.)	23	24	24
Air:Water Ratio	150	150	150
Blower BHP	1.9	2	2.1
Carbon Absorbtion Unit			
Number of Units	2	4	4
Diameter (ft.)	4	4	6
Height (ft.)	6	6	6

TABLE 3

SUMMARY OF CAPITAL AND ANNUAL COSTS

Air Stripping Option	Air Stripping % Removal	Capital Cost	Annualized Capital Cost*	Annual Operating & Maintenance Cost	Total Annual Cost*
A	90	$465,200	$129,100	$40,300	$169,400
A	95	466,300	129,400	40,400	169,800
A	99	469,600	130,300	40,900	171,200
B	90	474,100	131,300	40,300	171,800
B	95	475,400	131,900	40,400	172,300
B	99	479,500	133,000	40,900	173,900
C	90	586,000	162,600	40,400	203,000
C	95	588,000	163,100	40,500	203,600
C	99	592,800	164,400	40,900	205,300
Carbon Adsorption Option	**% Removal**				
A	99+	$500,600	$138,900	$ 85,300	$224,200
B	99+	531,500	147,400	95,300	242,700
C	99+	653,500	181,300	110,300	291,600

*Based on 5-year life at 12 percent interest.

TABLE 4

SUMMARY OF OVERALL REMOVAL EFFICIENCIES

Air Stripping Option	Air Stripping % Removal	Solvent Discharged to Storm Sewer lbs/yr*	Overall Removal (percent)	Average Concentration (μg/L)	Highest Concentration from Untreated Well (μg/L)
A	90	700	36	530	1,500
A	95	680	38	520	1,500
A	99	660	40	500	1,500
B	90	410	62	310	800
B	95	380	65	280	800
B	99	340	69	250	800
C	90	250	77	190	400
C	95	200	82	150	400
C	99	160	85	120	400
Carbon Adsorption Option	**% Removal**				
A	99+	660	40	500	1,500
B	99+	340	69	250	800
C	99+	160	85	120	400

*Rounded to two significant figures.

Appendix A

AIR STRIPPING PILOT STUDY REPORT

RECOVERY WELL

HENNEPIN AVENUE SITE

MINNEAPOLIS, MN

prepared for
BARR ENGINEERING CO./GENERAL MILLS, INC.

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1 SUMMARY

This study was conducted by Hydro Group's Environmental Products Divison for Barr Engineering, a consultant hired by General Mills, Inc. The purpose of the testing program was to investigate air stripping as a treatment methodology for removal of TCE, toluene and other laboratory solvents from contaminated groundwater at the Hennepin site, and to generate design recommendations for several different full-scale units.

The test results show, as expected, that air stripping is a very feasible alternative for volatile organics control at the Hennepin Avenue site. Removal efficiencies of over 99% for TCE were obtained with the pilot-scale equipment. This report contains full-scale design recommendations for removal efficiencies in the 90 to 99% range, to meet Minnesota Pollution Control Agency Requirements, at two different waterflows, to allow for different recovery options.

2 DESCRIPTION OF TEST EQUIPMENT

The pilot air stripper used in the test was developed by the Environmental Products Division as a portable unit capable of duplicating conditions found in full-scale treatment systems. This packed column has been used at over 40 sites throughout the country for pilot studies similar to this one. Results from these tests are compiled in a computerized database for use in data interpretation.

The unit is 21 feet high (to contain a packed bed depth of 15 feet) by 10 inches in diameter. Polypropylene Tri-Packs (2" nominal size) were used for the tower packing for Runs #1-6. Previous pilot testing with a variety of packings has shown that Tri-packs exhibit good mass transfer characteristics and also have a very low pressure drop, a factor which is very important in minimizing operating power requirements. In addition, two runs were performed with a new packing (2" Nor-pac) to examine its operating characteristics. The column is provided with sample taps at the raw water influent and every 5' through the packed bed. Samples at Hennepin Avenue were taken at the raw and

15' levels.

Air is provided to the column by a small, gasoline engine powered blower. The blower is capable of delivering up to 300 cfm at the static pressures encountered in the pilot stripper.

Process monitoring is achieved by a propeller-type self-powered analog flow meter (0-18 gpm) mounted in the inlet piping to gauge water flows. Air flows are measured using a pitot tube (placed in the air exhaust downcomer) connected to an inclined tube manometer. The air exhaust downcomer is one adaptation that had to be made on a pilot-scale unit; on a full-scale unit the air escapes to the atmosphere at the top of the column. The pressure drop across the packed bed at the various air flow rates is determined by a manometer; this also serves as a cross-check on the air flow meter, since a given air flow should repeatedly produce the same pressure drop from test to test. Pressure drops recorded at Hennepin Avenue correlated well with data from other sites.

3 TESTING PROCEDURE

Air stripping of volatile organic compounds is accomplished in the tower by the use of counter-current flows; that is, raw water is piped to the top of the tower and distributed over the surface of the packing, while air is forced into the bottom of the tower and blown upwards through the packing and the falling water. The packing causes an intimate mixing of the air and water, and the volatile organics are transfered across the air/water interface. Three major factors control this mass transfer process:

> Packing Height -- the depth of packing is the strongest single influence on removal efficiency. The greater the packed bed depth, the better the removal. This factor may be examined through comparison of samples taken at different heights of the tower, and can also be very easily modelled using traditional mass transfer calculations.
>
> Tower Diameter -- the diameter of the tower controls the liquid loading rate (measured in gpm/sq.ft.). A lower liquid loading rate will

improve removal efficiencies, but may cost more in capital outlay for the tower. This variable is controlled in the pilot testing by varying the water flow to the column.

Air-to-Water Ratio -- the air:water ratio (expressed in this report on a volume:volume basis) is most strongly a function of the compound being stripped. Higher air:water ratios will provide better removal rates, but have the disadvantage of increasing the size of the blower required and its associated power costs.

The procedure developed for the tests at Hennepin Avenue were designed to examine these variables within the framework of Hydro Group's past experience with laboratory solvents. The testing program included two water flow rates (15 and 25 gpm/sq ft) and three air:water ratios (50, 100, and 150:1), for a total of six combinations. These conditions are listed with their associated run numbers in Table I.

At the beginning of the testing, the column was flushed with water from the well to eliminate any chance of cross-contamination from other sites. Each of the operating conditions were allowed to run for at least twenty minutes to allow the process to come to equilibrium before samples were taken. Water flow, air flow and static pressure were monitored throughout the testing.

Water samples taken in accordance with standard accepted procedures for volatile organic analysis. The samples were turned over at the end of the day to Barr Engineering personnel who delivered them to the testing laboratory.

4 RESULTS

The samples taken were tested for volatile organics by Sanitary Engineering laboratories, Inc. Copies of all raw data are contaied in the Appendix to this report. The results from

Serco are tabulated in Table I.

5 DATA INTERPRETATION

The results were analyzed to determine mass transfer coefficients using well-known chemical engineering equations. Mass transfer coefficients are used to reflect the efficiency of the unit as a whole, taking into account the various operating parameters discussed above. They are more indicative of tower performance than merely comparing percentage removals. These coefficients were then compared with results from previous testing, and an appropriate mass transfer coefficient was selected to be used in designing the full-scale tower.

The quality of the water analyses appeared to be very good. Most of the trends that are expected in a test such as this were evident (i.e. improved removal at lower liquid loading rates and higher air:water ratios). The results also correlated well with previous pilot results.

6 DESIGN PARAMETERS AND COST ESTIMATES

Several factors were taken into account in generating the full-scale designs. They include:

1) Removal of VOC's to acceptable levels for discharge

   Three different removal percentages were considered, 90%, 95% and 99% removal of the total organics listed in the Serco Lab Analysis. These percentages will remove many compounds to below lab limits.

2) The need to minimize tower height

   This was done to avoid any adverse reaction from neighboring residents. The tower may also be housed in a building with only the air exhaust stacks protruding through the roof.

3) Cost Optimization (both capital and operating)

This is done by keeping the physical size of the unit as small as possible, and also selecting a blower with a small horsepower requirement. Selecting a small blower will also alleviate any potential noise problem.

The six different designs outlined in this report achieve these design goals. They all run at comparatively low liquid loading rates (approximately 15 gpm/sq ft) and high air:water ratios (100 or 150:1). This is primarily to keep the tower height down. Lower liquid loading rates increase the diameter of the tower, and therefore also increase its cost. However, because of the low flow rates of these towers, the diameter change and cost differences are minimal. It should be noted that extremely low liquid loading rates (less than 10 gpm/sq ft) will not produce significantly better results, since the packing will not be totally wetted.

Low liquid loading rates also allow the use of high air:water ratios without having a high pressure drop. This minimizes blower horsepower requirements. For instance, the pressure drop of tower #6 (300 gpm, 99% removal) should be about 2.3" water, and the blower horsepower to deliver a 150:1 air to water ratio will be 2.5 BHP. Increasing the liquid loading rate from 15 gpm/sq ft to 25 gpm/sq ft will increase the pressure drop to 9" water and the blower horsepower to approximately 10.5 BHP.

The six different designs (shown in Table II) were based on water flow rates of 100-150 gpm and 300 gpm. Operating the towers at less than these rates will produce better results. For the tower flow range (100-150 gpm), these will be minor cost savings if the tower is sized for 100 instead of 150 gpm.

There are several factors that must be considered in using these design recommendations. The choice of packing is critical--it is very important that the packing selected for the full-scale unit be similar to the packing used in the pilot test. Runs #1-6 in the pilot test used 2" Tripacks; Runs #7 & 8 used 2" Nor-Pac, a packing recently introduced on the American market. The differences in performance is self-evident. Accordingly, all of the above designs are based on 2" Jaeger Tripacks.

In addition, the tower must be constructed so as to insure proper water distribution, not only at the top of the tower, but throughout the entire depth of packing. A uniform air distribution must also be provided. These goals can be achieved through proper selection of internal appurtenances on the tower. Hydro Group can assure the performance of these units based on our successful scale-up experience at other sites.

TABLE I.

PILOT TEST RESULTS-GENERAL MILLS
PACKING --TRIPAC

RUN	WF	A:W	HT ft.	CONTAMINANT	INFL	EFFL	%REM
001	15	50	15	TCE	1100	21	98.09
	15	50		TOLUENE	160	8	94.88
	15	50		CHLOROFORM	120	5	96
	15	50		1,2DICHLOROETHYLENE	110	3	97.09
	15	50		BENZENE	98	3	96.73
	15	50		1,1,1TRICHLOROETHANE	54	1	98.15
	15	50		XYLENE	32	3	91.25
	15	50		1,2DICHLOROETHANE	27	4	85.19
	15	50		PCE	20	2	92
002	15	100	15	TCE	1100	12	98.91
	15	100		TOLUENE	130	4	97.08
	15	100		CHLOROFORM	120	2	98.17
	15	100		1,2DICHLOROETHYLENE	100	1	98.6
	15	100		BENZENE	78	2	97.69
	15	100		1,1,1TRICHLOROETHANE	51	1	98.82
	15	100		XYLENE	30	0	97
	15	100		1,2DICHLOROETHANE	26	1	94.62
	15	100		PCE	20	1	96.5
003	15	150	15	TCE	960	7	99.25
	15	150		CHLOROFORM	130	2	98.85
	15	150		TOLUENE	130	2	98.23
	15	150		1,2DICHLOROETHYLENE	110	1	99.27
	15	150		BENZENE	82	1	98.41
	15	150		1,1,1TRICHLOROETHANE	56	0	99.29
	15	150		XYLENE	33	0	97.27
	15	150		1,2DICHLOROETHANE	29	1	97.59
	15	150		PCE	22	1	97.27
004	25	50	15	TCE	940	42	95.53
	25	50		TOLUENE	140	12	91.43
	25	50		CHLOROFORM	120	9	92.75
	25	50		1,2DICHLOROETHYLENE	110	6	94.36
	25	50		BENZENE	90	5	94.78
	25	50		1,1,1TRICHLOROETHANE	55	2	96.73
	25	50		XYLENE	31	3	90.65
	25	50		1,2DICHLOROETHANE	26	6	76.92
	25	50		PCE	21	2	89.52
005	25	100	15	TCE	980	23	97.65
	25	100		TOLUENE	190	9	95.16
	25	100		CHLOROFORM	130	6	95.77
	25	100		1,2DICHLOROETHYLENE	110	4	96.55
	25	100		BENZENE	95	3	96.63
	25	100		1,1,1TRICHLOROETHANE	55	1	97.82
	25	100		XYLENE	31	1	96.77
	25	100		1,2DICHLOROETHANE	27	3	87.41
	25	100		PCE	21	1	93.33

PILOT TEST RESULTS-GENERAL MILLS
PACKING --TRIPAC

RUN	WF	A:W	HT ft	CONTAMINANT	INFL	EFFL	%REM
006	25	150	15	TCE	1000	10	99.05
	25	150		CHLOROFORM	140	2	98.5
	25	150		TOLUENE	120	3	97.92
	25	150		1,2DICHLOROETHYLENE	110	1	98.91
	25	150		BENZENE	64	0	98.59
	25	150		1,1,1TRICHLOROETHANE	58	1	99.14
	25	150		1,2DICHLOROETHANE	28	1	95.71
	25	150		XYLENE	27	0	96.67
	25	150		PCE	21	1	96.19
07	15	50	15	TCE	1000	78	92.2
	15	50		TOLUENE	170	24	85.88
	15	50		CHLOROFORM	150	17	88.67
	15	50		1,2DICHLOROETHYLENE	100	10	90
	15	50		BENZENE	93	10	89.35
	15	50		1,1,1TRICHLOROETHANE	62	4	92.9
	15	50		XYLENE	32	6	82.81
	15	50		1,2DICHLOROETHANE	30	8	73.67
	15	50		PCE	21	3	85.71
* 008	25	50	15	TCE	1100	61	94.45
	25	50		TOLUENE	170	14	91.76
	25	50		CHLOROFORM	140	14	90
	25	50		1,2DICHLOROETHYLENE	110	10	91.36
	25	50		BENZENE	93	7	92.47
	25	50		1,1,1TRICHLOROETHANE	63	3	94.76
	25	50		XYLENE	30	4	88
	25	50		1,2DICHLOROETHANE	28	7	75
	25	50		PCE	22	3	88.64

*Runs #7 & 8 were performed with 2" Nor-pac

TABLE II

Design Recommendations

FLOW	150 gpm	300 gpm
% Removal	90	90
Diameter (ft)	3.5	4.5
Packing Height (ft)	8	10
Overall Height (ft)	16	18
A:W Ratio	150	100
Blower BHP	0.8	1
Estimated Cost	$19,500	$23,600
% Removal	95	95
Diameter (ft)	3.5	4.5
Packing Height (ft)	10	12
Overall Height (ft)	18	20
A:W Ratio	150	100
Blower BHP	1	1.25
Estimated Cost	$20,500	$25,100
% Removal	99	99
Diameter (ft)	3.5	5.0
Packing Height (ft)	16	16
Overall Height (ft)	24	24
A:W Ratio	150	150
Blower BHP	2	2.2
Estimated Cost	$23,500	$29,800

SERCO
1931 West County Road C2
Roseville, Minnesota 55113 (612) 636-7173

LABORATORY ANALYSIS REPORT NO: 5533 PAGE 1
07/05/84

Barr Engineering Company
6800 France Avenue South
Minneapolis, MN 55435

Ms. Suzanne Jiwani

DATE COLLECTED:
DATE RECEIVED: 06/28/84
COLLECTED BY: CLIENT
PICKED UP BY: CLIENT
SAMPLE TYPE: GROUNDWATER
GENERAL MILLS

SERCO SAMPLE NO:	13483	13487	13491	13495	13499
SAMPLE DESCRIPTION:	10:55 1-15	11:32 2-15	12:07 3-15	1:00 4-15	2:30 5-15
ANALYSIS:					
Benzene, ug/L	3.2	1.8	1.3**	4.7	3.2
Toluene, ug/L	8.2	3.8	2.3**	12	9.2
Xylene, total, ug/L	2.8**	<1.0	<1.0	2.9**	1.0**
Methylene chloride, ug/L	<3.0	<3.0	<3.0	<3.0	<3.0
1,1 Dichloroethane, ug/L	0.3**	0.1**	<0.1	0.5	0.3**
1,1 Dichloroethylene, ug/L	<0.1	<0.1	<0.1	<0.1	<0.1
1,2 Dichloroethylene, total ug/L	3.2	1.4	0.8	6.2	3.8
Chloroform, ug/L	4.8	2.2	1.5	8.7	5.5
1,2 Dichloroethane, ug/L	4.0	1.4	0.7	6.0	3.4
1,1,1 Trichloroethane, ug/L	1.0	0.6	0.4	1.8	1.2
ichloroethylene, ug/L	21	12	7.2	42	23
etrachloroethylene, ug/L	1.6	0.7	0.6	2.2	1.4

SERCO SAMPLE NO:	13503	13507	13511	13515	13516
SAMPLE DESCRIPTION:	3:35 6-15	4:55 7-15	5:37 8-15	10:50 R-1	10:50 R-1
ANALYSIS:					
Benzene, ug/L	<1.0	9.9	7.0	93	-
Toluene, ug/L	2.5**	24	14	160	-
Xylene, total, ug/L	<1.0	5.5	3.6**	32	-
Methylene chloride, ug/L	<3.0	<3.0	<3.0	<3.0	-
1,1 Dichloroethane, ug/L	<0.1	1.0	1.0	12	-

Approved by:

< means "not detected at this level"

continued

SERCO

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LABORATORY ANALYSIS REPORT NO: 5538 PAGE 2
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SERCO SAMPLE NO:	13503	13507	13511	13515	13516
SAMPLE DESCRIPTION:	3:35 6-15	4:55 7-15	5:37 8-15	10:50 R-1	10:50 R-1
ANALYSIS:					
1,1 Dichloroethylene, ug/L	<0.1	<0.1	<0.1	1.4	-
,2 Dichloroethylene, total ug/L	1.2	10	9.5	110	-
Chloroform, ug/L	2.1	17	14	120	-
1,2 Dichloroethane, ug/L	1.2	7.9	7.0	27	-
1,1,1 Trichloroethane, ug/L	0.5	4.4	3.3	54	-
Trichloroethylene, ug/L	9.5	78	51	>770	1100*
Tetrachloroethylene, ug/L	0.8	3.0	2.5	20	-

SERCO SAMPLE NO:	13519	13520	13523	13524	13527
SAMPLE DESCRIPTION:	11:27 R-2	11:27 R-2	12:00 R-3	12:00 R-3	12:50 R-4
ANALYSIS:					
nzene, ug/L	78	-	82	-	90
Toluene, ug/L	130	-	130	-	140
Xylene, total, ug/L	30	-	33	-	31
Methylene chloride, ug/L	<3.0	-	<3.0	-	<3.0
1,1 Dichloroethane, ug/L	11	-	12	-	12
1,1 Dichloroethylene, ug/L	2.3	-	1.7	-	1.5
1,2 Dichloroethylene, total ug/L	100	-	110	-	110
Chloroform, ug/L	120	-	130	-	120
1,2 Dichloroethane, ug/L	26	-	29	-	26
1,1,1 Trichloroethane, ug/L	51	-	56	-	55

Approved by: GJO < means "not detected at this level" continued

SANITARY ENGINEERING LABORATORIES, INC.

MEMBER

SERCO
1931 West County Road C2
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LABORATORY ANALYSIS REPORT NO: 5538 PAGE 3
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SERCO SAMPLE NO:	13519	13520	13523	13524	13527
SAMPLE DESCRIPTION:	11:27 R-2	11:27 R-2	12:00 R-3	12:00 R-3	12:50 R-4
ANALYSIS:					
Trichloroethylene, ug/L	>770	1100*	>790	960*	>780
etrachloroethylene, ug/L	20	-	22	-	21

SERCO SAMPLE NO:	13528	13533	13531	13538	13535
SAMPLE DESCRIPTION:	12:50 R-4	2:25 R-5	2:25 R-5	3:00 R-6	3:00 R-6
ANALYSIS:					
Benzene, ug/L	-	95	-	64	-
Toluene, ug/L	-	190	-	120	-
Xylene, total, ug/L	-	31	-	27	-
Methylene chloride, ug/L	-	<3.0	-	<3.0	-
1,1 Dichloroethane, ug/L	-	12	-	12	-
1 Dichloroethylene, ug/L	-	2.2	-	2.0	-
,2 Dichloroethylene, total ug/L	-	110	-	110	-
Chloroform, ug/L	-	130	-	140	-
1,2 Dichloroethane, ug/L	-	27	-	28	-
1,1,1 Trichloroethane, ug/L	-	55	-	58	-
Trichloroethylene, ug/L	940*	>780	930*	>800	1000*
Tetrachloroethylene, ug/L	-	21	-	21	-

Approved by: [signature]   < means "not detected at this level"   continued

MEMBER

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SERCO SAMPLE NO:	13539	13540	13543	13544	13548
SAMPLE DESCRIPTION:	4:50 R-7	4:50 R-7	5:30 R-8	5:30 R-8	109 GM RJM 6-27-84 0900HRS
ANALYSIS:					
Benzene, ug/L	93	-	93	-	95
Toluene, ug/L	170	-	170	-	140
Xylene, total, ug/L	32	-	30	-	39
Methylene chloride, ug/L	<3.0	-	<3.0	-	<3.0
1,1 Dichloroethane, ug/L	12	-	12	-	11
1,1 Dichloroethylene, ug/L	1.3	-	1.4	-	1.4
1,2 Dichloroethylene, total ug/L	100	-	110	-	99
Chloroform, ug/L	150	-	140	-	140
1,2 Dichloroethane, ug/L	30	-	28	-	30
1,1,1 Trichloroethane, ug/L	62	-	63	-	55
Trichloroethylene, ug/L	>780	1000*	>800	1100*	>760
Tetrachloroethylene, ug/L	21	-	22	-	21

SERCO SAMPLE NO:	13547	13551	13553	13554	13557
SAMPLE DESCRIPTION:	109 GM RJM 6-27-84 0900HRS	109 GM RJM F-BLANK 0900HRS	109 GM RJM 6-27-84 1730	109 GM RJM 6-27-84 1730	BLANK OF 6-22-84
ANALYSIS:					
Benzene, ug/L	-	<1.0	66	-	<1.0
Toluene, ug/L	-	<1.0	170	-	<1.0
Xylene, total, ug/L	-	<1.0	31	-	<1.0
Methylene chloride, ug/L	-	<3.0	<3.0	-	3.1
1,1 Dichloroethane, ug/L	-	<0.1	12	-	<0.1

Approved by: [illegible] < means "not detected at this level" continued

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SERCO SAMPLE NO:	13547	13551	13553	13554	13557
SAMPLE DESCRIPTION:	109 GM RJM 6-27-84 0900HRS	109 GM RJM F-BLANK 0900HRS	109 GM RJM 6-27-84 1730	109 GM RJM 6-27-84 1730	BLANK OF 6-22-84
ANALYSIS:					
1,1 Dichloroethylene, ug/L	-	<0.1	1.7	-	<0.1
1,2 Dichloroethylene, total ug/L	-	<0.1	110	-	<0.1
Chloroform, ug/L	-	<0.4	130	-	<0.4
1,2 Dichloroethane, ug/L	-	<0.1	28	-	<0.1
1,1,1 Trichloroethane, ug/L	-	<0.1	55	-	<0.1
Trichloroethylene, ug/L	900*	<0.8	>770	960*	<0.8
Tetrachloroethylene, ug/L	-	0.2**	21	-	<0.1

SERCO SAMPLE NO:	13558	13560
SAMPLE DESCRIPTION:	109 FIELD BLANK 1045	FIELD BLANK 2:00 PM
ANALYSIS:		
Benzene, ug/L	<1.0	1.1**
Toluene, ug/L	<1.0	<1.0
Xylene, total, ug/L	<1.0	<1.0
Methylene chloride, ug/L	<3.0	<3.0
1,1 Dichloroethane, ug/L	<0.1	<0.1
1,1 Dichloroethylene, ug/L	<0.1	<0.1
1,2 Dichloroethylene, total ug/L	<0.1	<0.1
Chloroform, ug/L	<0.4	<0.4
1,2 Dichloroethane, ug/L	<0.1	<0.1
1,1,1 Trichloroethane, ug/L	<0.1	<0.1

Approved by: [signature] < means "not detected at this level"

continued

SERCO

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LABORATORY ANALYSIS REPORT NO: 5538 PAGE 6
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SERCO SAMPLE NO:	13558	13560
SAMPLE DESCRIPTION:	109 FIELD BLANK	FIELD BLANK
ANALYSIS:	1045	2:00 PM
Trichloroethylene, ug/L	<0.8	<0.8
trachloroethylene, ug/L	<0.1	<0.1

All analyses were performed using EPA or other recognized methodologies.

Report submitted by,

Anne L. Ochs
Project Manager

* 1:20 dilution
** Concentration below Method Detection Limit, indicating the presence of the compound below a level of reliable quantification.

< means "not detected at this level"

MEMBER

Appendix

APPENDIX B

DETAILED COSTS

TABLE B-1
AIR STRIPPING TREATMENT

OPTION A: Treat Well 109
Discharge Wells 108, 110, 111, 112 and 113 to Storm Sewer Without Treatment

I. Capital Costs

Item	Unit	Estimated Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
Electric Service Hookup	Ea.	1	1,500.00	1,500.00
F&I Air Stripper				
- 99% Removal	L.S.	1	27,000.00	27,000.00
- 95% Removal	L.S.	1	24,600.00	24,600.00
- 90% Removal	L.S.	1	23,800.00	23,800.00
Air Stripper Controls	L.S.	1	2,000.00	2,000.00
Concrete Block Building	L.S.	1	10,000.00	10,000.00
Gravity Discharge Pipeline	L.F.	120	30.00	3,600.00
Discharge Pipeline Manhole	Ea.	1	1,000.00	1,000.00
Street Restoration	S.Y.	2	75.00	150.00
		Subtotal -	99% Removal	$ 47,300.00
			95% Removal	$ 44,900.00
			90% Removal	$ 44,100.00
B. WELL 108, 109 AND 110 DISCHARGE PIPING				
Mobilization	L.S.	1	$ 2,000.00	$ 2,000.00
F&I Forcemain	L.F.	200	17.00	3,400.00
Parking Lot Restoration	S.Y.	10	2.50	250.00
Peat Disposal	C.Y.	190	10.00	1,900.00
Granular Borrow	C.Y.	190	10.00	1,900.00
Saw Cutting	L.F.	300	3.00	900.00
Street Removal	S.Y.	300	5.00	1,500.00
Street Replacement	S.Y.	300	50.00	15,000.00
Air Break Piping	Ea.	2	1,500.00	3,000.00
Gravity Discharge Pipeline	L.F.	45	30.00	1,350.00
			Subtotal	$ 31,200.00

C. WELL 108, 109, 110 AND APPURTENANCES

Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
Install Well 108	L.S.	1	8,000.00	8,000.00
Install Well 109	L.S.	1	18,000.00	18,000.00
Install Well 110	L.S.	1	18,000.00	18,000.00
F&I Pump	Ea.	3	2,000.00	6,000.00
F&I Pitless Unit	Ea.	2	2,000.00	4,000.00
Well Level Switches	Well	3	250.00	750.00
Electric Service Hookup	Ea.	2	1,500.00	3,000.00
			Subtotal	$ 59,800.00

D. WELL 111, 112 AND 113 DISCHARGE PIPING

Mobilization	L.S.	1	$ 5,050.00	$ 5,050.00
F&I 3" Diameter Forcemain	L.F.	400	17.00	6,800.00
F&I 6" Diameter Forcemain	L.F.	800	20.00	16,000.00
Peat Disposal	C.Y.	1,320	10.00	13,200.00
Granular Borrow	C.Y.	1,320	10.00	13,200.00
Saw Cutting	L.F.	2,400	3.00	7,200.00
Street Removal	S.Y.	1,200	5.00	6,000.00
Street Replacement	S.Y.	1,200	50.00	60,000.00
Air Break Piping	Ea.	1	2,000.00	2,000.00
Gravity Discharge Piping	L.F.	25	30.00	750.00
			Subtotal	$130,200.00

E. WELL 111, 112, 113 AND APPURTENANCES

Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
Install Wells 111,112,113	Ea.	3	18,000.00	54,000.00
F&I Pump	Ea.	3	2,000.00	6,000.00
F&I Pitless Unit	Ea.	3	2,000.00	6,000.00
F&I Meter Manhole	Ea.	3	2,000.00	6,000.00
Well Level Switches	Well	3	250.00	750.00
Electric Service Hookup	Well	3	1,500.00	4,500.00
			Subtotal	$ 79,300.00

F. ENGINEERING COSTS (15%)

99% Removal	$ 52,200.00
95% Removal	51,800.00
90% Removal	51,700.00

G. CONTINGENCIES (20%)

99% Removal	$ 69,600.00
95% Removal	69,100.00
90% Removal	68,900.00

OPTION A TOTAL CAPITAL COST - 99% REMOVAL	$469,600.00
95% REMOVAL	$466,300.00
90% REMOVAL	$465,200.00

II. Operating and Maintenance Costs

Item	Unit	Estimated Annual Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Electricty for Air Stripper Blower				
- 99% Removal	kw-hr	12,500	0.07	$ 875.00
- 95% Removal	kw-hr	5,900	0.07	400.00
- 90% Removal	kw-hr	4,600	0.07	325.00
Air Stripper Blower Maintenance and Replacement Cost (15% of Purchase Price)	L.S.	1	225.00	225.00
Equipment Monitoring	L.S.	1	5,000.00	5,000.00
		Subtotal	99% Removal	$ 6,100.00
			95% Removal	5,625.00
			90% Removal	5,550.00
B. PUMPING				
Electricity for Well 108 Pump	kw-hr	20,000	$ 0.07	$ 1,400.00
Electricity for Well 109 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 110 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 111 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 112 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 113 Pump	kw-hr	20,000	0.07	1,400.00
Maintenance and Replacement Costs (15% of Purchase Price)	Well	6	225.00	1,350.00
			Subtotal	$ 9,750.00
C. Monitoring & Reports				$ 25,000.00

OPTION A TOTAL ANNUAL OPERATING & MAINTENANCE COST

99% Removal	$ 40,900.00
95% Removal	40,400.00
90% Removal	40,300.00

OPTION B: Treat Wells 108 and 109
Discharge Wells 110, 111, 112 and 113 to Storm Sewer Without Treatment

I. Capital Costs

Item	Unit	Estimated Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
Electric Service Hookup	Ea.	1	1,500.00	1,500.00
F&I Air Stripper				
- 99% Removal	L.S.	1	31,500.00	31,500.00
- 95% Removal	L.S.	1	28,500.00	28,500.00
- 90% Removal	L.S.	1	27,500.00	27,500.00
Air Stripper Controls	L.S.	1	3,000.00	3,000.00
Concrete Block Building	L.S.	1	10,000.00	10,000.00
Gravity Discharge Pipeline	L.S.	120	30.00	3,600.00
Discharge Pipeline Manhole	Ea.	1	1,000.00	1,000.00
Street Restoration	S.Y.	2	75.00	150.00
		Subtotal -	99% Removal	$ 52,800.00
			95% Removal	$ 49,800.00
			90% Removal	$ 48,800.00
B. WELL 108, 109 AND 110 DISCHARGE PIPING				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
F&I Forcemain	L.F.	300	17.00	5,100.00
Pole Barn Work	L.S.	1	500.00	500.00
Parking Lot Restoration	S.Y.	60	2.50	150.00
Peat Disposal	C.Y.	190	10.00	1,900.00
Granular Borrow	C.Y.	190	10.00	1,900.00
Saw Cutting	L.F.	300	3.00	900.00
Street Removal	S.Y.	300	5.00	1,500.00
Street Replacement	S.Y.	300	50.00	15,000.00
Air Break Piping	Ea.	1	1,500.00	1,500.00
Gravity Discharge Pipeline	L.F.	20	30.00	600.00
			Subtotal	$ 31,100.00
C. WELL 108, 109, 110 AND APPURTENANCES				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
Install Well 108	L.S.	1	8,000.00	8,000.00

Install Well 109	L.S.	1	18,000.00	18,000.00
Install Well 110	L.S.	1	18,000.00	18,000.00
F&I Pump	Ea.	3	2,000.00	6,000.00
F&I Pitless Unit	Ea.	3	2,000.00	6,000.00
Well Level Switches	Well	3	250.00	750.00
Electric Service Hookup	Ea.	2	1,500.00	3,000.00
			Subtotal	$ 61,800.00

D. WELL 111, 112 AND 113 DISCHARGE PIPING

No change from Option A. See itemized costs under Option A, Subsection I.D.

Subtotal $130,200.00

E. WELL 111, 112, 113 AND APPURTENANCES

No change from Option A. See itemized costs under Option A, Subsection I.E.

Subtotal $ 79,300.00

F. ENGINEERING COSTS (15%)

99% Removal	$ 53,300.00
95% Removal	52,800.00
90% Removal	52,700.00

G. CONTINGENCIES (20%)

99% Removal	$ 71,000.00
95% Removal	70,400.00
90% Removal	70,200.00

OPTION B TOTAL CAPITAL COST

99% Removal	$479,500.00
95% Removal	$475,400.00
90% Removal	$474,100.00

II. Operating and Maintenance Costs

Item	Unit	Estimated Annual Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Electricty for Air Stripper Blower				
- 99% Removal	kw-hr	13,000	$ 0.07	$ 910.00
- 95% Removal	kw-hr	6,500	0.07	450.00
- 90% Removal	kw-hr	5,200	0.07	360.00
Air Stripper Blower Maintenance and Replacement Cost (15% of Purchase Price)	L.S.	1	225.00	225.00
Equipment Monitoring	L.S.	1	5,000.00	5,000.00
		Subtotal	99% Removal	$ 6,135.00
			95% Removal	5,675.00
			90% Removal	5,585.00

B. PUMPING

Electricity for Well 108 Pump	kw-hr	20,000	$ 0.07	$ 1,400.00
Electricity for Well 109 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 110 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 111 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 112 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 113 Pump	kw-hr	20,000	0.07	1,400.00
Maintenance and Replacement Costs (15% of Purchase Price)	Well	6	225.00	1,350.00
			Subtotal	$ 9,750.00

C. Monitoring & Report $ 25,000.00

OPTION B TOTAL ANNUAL OPERATING & MAINTENANCE COST

99% Removal	$ 40,900.00
95% Removal	40,400.00
90% Removal	40,300.00

OPTION C: Treat Wells 108, 109 and 110
Discharge Wells 111, 112 and 113 to Strom Sewer Without Treatment

I. Capital Costs

Item	Unit	Estimated Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
Electric Service Hookup	Ea.	1	1,500.00	1,500.00
F&I Air Stripper				
- 99% Removal	L.S.	1	35,000.00	35,000.00
- 95% Removal	L.S.	1	31,500.00	31,500.00
- 90% Removal	L.S.	1	30,000.00	30,000.00
Air Stripper Controls	L.S.	1	5,000.00	5,000.00
Concrete Block Building	L.S.	1	10,000.00	10,000.00
Gravity Discharge Pipeline	L.F.	120	30.00	3,600.00
Discharge Pipeline Manhole	Ea.	1	1,000.00	1,000.00
Street Restoration	S.Y.	2	75.00	150.00
		Subtotal -	99% Removal	$ 58,300.00
			95% Removal	$ 54,800.00
			90% Removal	$ 53,300.00
B. WELL 108, 109 AND 110 DISCHARGE PIPING				
Mobilization	L.S.	1	$ 5,000.00	$ 5,000.00
F&I Forcemain	L.F.	1,200	17.00	20,400.00
Parking Lot Restoration	S.Y.	80	2.50	200.00
Peat Disposal	C.Y.	1,100	10.00	11,000.00
Granular Borrow	C.Y.	1,100	10.00	11,000.00
Saw Cutting	L.F.	1,800	3.00	5,400.00
Street Removal	S.Y.	800	5.00	4,000.00
Street Replacement	S.Y.	800	50.00	40,000.00
Forcemain Railroad Crossing	L.S.	1	10,000.00	10,000.00
F&I Air Relief Manhole	L.S.	1	2,500.00	2,500.00
			Subtotal	$109,500.00

C. WELL 108, 109, 110 AND APPURTENANCES

No change from Option B costs. See itemized costs under Option B, Subsection I.C.

Subtotal $ 61,800.00

D. WELL 111, 112 AND 113 DISCHARGE PIPING

No change from Option A. See itemized costs under Option A, Subsection I.D.

Subtotal	$130,200.00

E. WELL 111, 112, 113 AND APPURTENANCES

No change from Option A. See itemized costs under Option A, Subsection I.E.

Subtotal	$ 79,300.00

F. ENGINEERING COSTS (15%)

99% Removal	$ 65,900.00
95% Removal	65,300.00
90% Removal	65,100.00

G. CONTINGENCIES (20%)

99% Removal	$ 87,800.00
95% Removal	87,100.00
90% Removal	$ 86,800.00

OPTION C TOTAL CAPITAL COST

99% Removal	$592,800.00
95% Removal	$588,000.00
90% Removal	$586,000.00

II. Operating and Maintenance Costs

Item	Unit	Estimated Annual Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Electricty for Air Stripper Blower				
- 99% Removal	kw-hr	13,700	$ 0.07	$ 960.00
- 95% Removal	kw-hr	7,200	0.07	500.00
- 90% Removal	kw-hr	5,900	0.07	400.00
Air Stripper Blower Maintenance and Replacement Cost (15% of Purchase Price)	L.S.	1	225.00	225.00
Equipment Monitoring	L.S.	1	5,000.00	5,000.00
		Subtotal	99% Removal	$ 6,185.00
			95% Removal	5,725.00
			90% Removal	5,625.00
B. PUMPING				
Electricity for Well 108 Pump	kw-hr	20,000	$ 0.07	$ 1,400.00
Electricity for Well 109 Pump	kw-hr	20,000	0.07	1,400.00

Electricity for Well 110 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 111 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 112 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 113 Pump	kw-hr	20,000	0.07	1,400.00
Maintenance and Replacement Costs (15% of Purchase Price)	Well	6	225.00	1,350.00
			Subtotal	$ 9,750.00

C. Monitoring & Reports $ 25,000.00

OPTION C TOTAL ANNUAL OPERATING & MAINTENANCE COST

99% Removal	$ 40,900.00
95% Removal	40,500.00
90% Removal	40,400.00

TABLE B-2
CARBON ABSORBTION TREATMENT

OPTION A: Treat Well 109
Discharge Wells 108, 110, 111, 112 and 113 to Storm Sewer Without Treatment

I. Capital Costs

Item	Unit	Estimated Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
F&I Carbon Absorbtion Apparatus	L.S.	1	50,000.00	50,000.00
Electric Service Hookup	L..S	1	1,500.00	1,500.00
Controls	L.S.	1	2,000.00	2,000.00
Concrete Block Building	L..S	1	10,000.00	10,000.00
Gravity Discharge Pipeline	L.F.	120	30.00	3,600.00
Discharge Pipeline Manhole	Ea.	1	1,000.00	1,000.00
Street Restoration	S.Y.	2	75.00	150.00
			Subtotal	$ 70,300.00

B. WELL 108, 109 AND 110 DISCHARGE PIPING

No change from Air Stripper Treatment, Option A. See itemized costs under Air Stripper Treatment, Option A, Subsection I.B.

Subtotal $ 31,200.00

C. WELL 108, 109, 110 AND APPURTENANCES

No change from Air Stripper Treatment, Option A. See itemized costs under Air Stripper Treatment, Option A, Subsection I.C.

Subtotal $ 59,800.00

D. WELL 111, 112 AND 113 DISCHARGE PIPING

No change from Air Stripper Treatment, Option A. See itemized costs under Air Stripper Treatment, Option A, Subsection I.D.

Subtotal $130,200.00

E. WELL 111, 112, 113 AND APPURTENANCES

No change from Air Stripper Treatment, Option A. See itemized cots under Air Stripper Treatment, Option A, Subsection I.E.

Subtotal $ 79,300.00

F. ENGINEERING COSTS (15%) $ 55,600.00

G. CONTINGENCIES (20%) $ 74,200.00

OPTION A TOTAL CAPTIAL COST $500,600.00

II. Operating and Maintenance Costs

Item	Unit	Estimated Annual Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Operator	Hr.	500	$ 30.00	$ 15,000.00
Carbon	L.S.	1	25,000.00	25,000.00
Building Heat	L.S.	1	550.00	550.00
			Subtotal	$ 40,550.00
B. PUMPING				
Electricity for Well 108 Pump	kw-hr	20,000	$ 0.07	$ 1,400.00
Electricity for Well 109 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 110 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 111 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 112 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 113 Pump	kw-hr	20,000	0.07	1,400.00
Maintenance and Replacement Costs (15% of Purchase Price)	Well	6	225.00	1,350.00
			Subtotal	$ 9,750.00
C. Monitoring & Reports				$ 35,000.00

OPTION A TOTAL ANNUAL OPERATING & MAINTENANCE COST $ 85,300.00

OPTION B: Treat Wells 108 and 109
Discharge Wells 110, 111, 112 and 113 to Storm Sewer Without Treatment

I. Capital Costs

Item	Unit	Estimated Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
F&I Carbon Absorbtion Apparatus	L.S.	1	70,000.00	70,000.00
Electric Service Hookup	L.S.	1	1,500.00	1,500.00
Controls	L..S	1	3,000.00	3,000.00
Concrete Block Building	L.S.	1	10,000.00	10,000.00
Gravity Discharge Pipeline	L.F.	120	30.00	3,600.00
Discharge Pipeline Manhole	Ea.	1	1,000.00	1,000.00
Street Restoration	S.Y.	2	75.00	150.00
			Subtotal	$ 91,300.00

B. WELL 108, 109 AND 110 DISCHARGE PIPING

No change from Air Stripper Treatment, Option B. See itemized costs under Air Stripper Treatment, Option B, Subsection I.B.

Subtotal $ 31,100.00

C. WELL 108, 109, 110 AND APPURTENANCES

No change from Air Stripper Treatment, Option B. See itemized costs under Air Stripper Treatment, Option B, Subsection I.C.

Subtotal $ 61,800.00

D. WELL 111, 112 AND 113 DISCHARGE PIPING

No change from Air Stripper Treatment, Option A. See itemized costs under Option A, Subsection I.D.

Subtotal $130,200.00

E. WELL 111, 112, 113 AND APPURTENANCES

No change from Air Stripper Treatment, Option A. See itemized costs Under Option A, Subsection I.E.

Subtotal $ 79,300.00

F. ENGINEERING COSTS (15%) $ 59,100.00

G. CONTINGENCIES (20%) $ 78,700.00

	OPTION B TOTAL CAPITAL COST			$531,500.00

II. Operating and Maintenance Costs

Item	Unit	Estimated Annual Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Operator	Hr.	500	$ 30.00	$ 15,000.00
Carbon	L.S.	1	35,000.00	35,000.00
Building Heat	L.S.	1	550.00	550.00
			Subtotal	$ 50,550.00
B. PUMPING				
Electricity for Well 108 Pump	kw-hr	20,000	$ 0.07	$ 1,400.00
Electricity for Well 109 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 110 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 111 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 112 Pump	kw-hr	20,000	0.07	1,400.00
Electricity for Well 113 Pump	kw-hr	20,000	0.07	1,400.00
Maintenance and Replacement Costs (15% of Purchase Price)	Well	6	225.00	1,350.00
			Subtotal	$ 9,750.00
C. Monitoring & Reports				$ 35,000.00
	OPTION B TOTAL ANNUAL OPERATING & MAINTENANCE COST			$ 95,300.00

OPTION C: Treat Wells 108, 109 and 110
Discharge to Wells 111, 112 and 113 to Storm Sewer Without Treatment

I. Capital Costs

Item	Unit	Estimated Quantity	Estimated Unit Price	Extension
A. TREATMENT				
Mobilization	L.S.	1	$ 2,050.00	$ 2,050.00
F&I Carbon Absorbtion Apparatus	L.S.	1	80,000.00	80,000.00
Electric Service Hookup	L.S.	1	1,500.00	1,500.00
Controls	L.S.	1	5,000.00	5,000.00
Concrete Block Building	L.S.	1	10,000.00	10,000.00
Gravity Discharge Pipeline	L.F.	120	30.00	3,600.00
Discharge Pipeline Manhole	Ea.	1	1,000.00	1,000.00
Street Restoration	S.Y.	2	75.00	150.00
			Subtotal	$103,300.00

B. WELL 108, 109 AND 110 DISCHARGE PIPING

No change from Air Stripper Treatment, Option C. See itemized costs under Air Stripper Treatment, Option C, Subsection I.B.

Subtotal $109,500.00

C. WELL 108, 109, 110 AND APPURTENANCES

No change from Air Stripper Treatment, Option B. See itemized costs under Air Stripper Treatment Option B, Subsection I.C.

Subtotal $ 61,800.00

D. WELL 111, 112 AND 113 DISCHARGE PIPING

No change from Air Stripper Treatment, Option A. See itemized costs under Air Stripper Treatment, Option A, Subsection I.D.

Subtotal $130,200.00

E. WELL 111, 112, 113 AND APPURTENANCES

No change from Air Stripper Treatment, Option A. See itemized costs under Air Stripper Treatment, Option A, Subsection I.E.

Subsection $ 79,300.00

F. ENGINEERING COST (15%) $ 72,600.00

G. CONTINGENCIES (20%) $ 96,800.00

OPTION C TOTAL CAPITAL COSTS $653,500.00

II. Operating and Maintenance Costs

Item		Unit	Estimated Annual Quantity	Estimated Unit Price	Extension
A.	TREATMENT				
	Operator	Hr.	500	$ 30.00	$ 15,000.00
	Carbon	L.S.	1	50,000.00	50,000.00
	Building Heat	L.S.	1	550.00	550.00
				Subtotal	$ 65,550.00
B.	PUMPING				
	Electricity for Well 108 Pump	kw-hr	20,000	$ 0.07	$ 1,400.00
	Electricity for Well 109 Pump	kw-hr	20,000	0.07	1,400.00
	Electricity for Well 110 Pump	kw-hr	20,000	0.07	1,400.00
	Electricity for Well 111 Pump	kw-hr	20,000	0.07	1,400.00
	Electricity for Well 112 Pump	kw-hr	20,000	0.07	1,400.00
	Electricity for Well 113 Pump	kw-hr	20,000	0.07	1,400.00
	Maintenance and Replacement Costs (15% of Purchase Price)	Well	6	225.00	1,350.00
				Subtotal	$ 9,750.00
C.	Monitoring & Reports				$ 35,000.00

OPTION C TOTAL ANNUAL OPERATING & MAINTENANCE COST $110,300.00

TABLE B-3

SUMMARY OF COSTS
PUMP-OUT WELL OPTION A

	Air Stripping Removal 90%	Air Stripping Removal 95%	Air Stripping Removal 99%	Carbon Adsorption
CAPITAL COST				
Treatment	$ 44,100	$ 44,900	$ 47,300	$ 70,300
Well 108, 109 & 110 Discharge Piping	31,200	31,200	31,200	31,200
Well 108, 109, 110 and Appurtenances	59,800	59,800	59,800	59,800
Well 111, 112 & 113 Discharge Piping	130,200	130,200	130,200	130,200
Well 111, 112, 113 and Appurtenances	79,300	79,300	79,300	79,300
Subtotal	$344,600	$345,400	$347,800	$370,800
Engineering (15%)	56,700	51,800	52,200	55,600
Contingency (20%)	68,900	69,100	69,600	74,200
TOTAL CAPITAL COST	$465,200	$466,300	$469,600	$500,600
ANNUAL COST				
Annual Capital Cost (5 years, 12% interest)	$129,100	$129,400	$130,300	$138,900
Annual Operating and Maintenance	40,300	40,400	40,900	85,300
TOTAL ANNUAL COST (first 5 years of operation)	$169,400	$169,800	$171,200	$224,200

TABLE B-4

SUMMARY OF COSTS
PUMP-OUT WELL OPTION B

	Air Stripping Removal 90%	Air Stripping Removal 95%	Air Stripping Removal 99%	Carbon Adsorption
CAPITAL COST				
Treatment	$ 48,800	$ 49,800	$ 52,800	$ 91,300
Well 108, 109 & 110 Discharge Piping	31,100	31,100	31,100	31,100
Well 108, 109, 110 and Appurtenances	61,800	61,800	61,800	61,800
Well 111, 112 & 113 Discharge Piping	130,200	130,200	130,200	130,200
Well 111, 112, 113 and Appurtenances	79,300	79,300	79,300	79,300
Subtotal	$351,200	$352,200	$355,200	$393,700
Engineering (15%)	52,700	52,800	53,300	59,100
Contingency (20%)	70,200	70,400	71,000	78,700
TOTAL CAPITAL COST	$474,100	$475,400	$479,500	$531,500
ANNUAL COST				
Annual Capital Cost (5 years, 12% interest)	$131,500	$131,900	$133,000	$147,400
Annual Operating and Maintenance	40,300	40,400	40,900	95,300
TOTAL ANNUAL COST (first 5 years of operation)	$171,800	$172,300	$173,900	$242,700

TABLE B-5

SUMMARY OF COSTS
PUMP-OUT WELL OPTION C

	Air Stripping Removal 90%	Air Stripping Removal 95%	Air Stripping Removal 99%	Carbon Adsorption
CAPITAL COST				
Treatment	$ 53,300	$ 54,800	$ 58,300	$103,300
Well 108, 109 & 110 Discharge Piping	109,500	109,500	109,500	109,500
Well 108, 109, 110 and Appurtenances	61,800	61,800	61,800	61,800
Well 111, 112 & 113 Discharge Piping	130,200	130,200	130,200	130,200
Well 111, 112, 113 and Appurtenances	79,300	79,300	79,300	79,300
Subtotal	$434,100	$435,600	$439,100	$484,100
Engineering (15%)	65,100	65,300	65,900	72,600
Contingency (20%)	86,800	87,100	87,800	96,800
TOTAL CAPITAL COST	$586,000	$588,000	$592,800	$653,500
ANNUAL COST				
Annual Capital Cost (5 years, 12% interest)	$162,600	$163,100	$164,400	$181,300
Annual Operating and Maintenance	40,400	40,500	40,900	110,300
TOTAL ANNUAL COST (first 5 years of operation)	$203,000	$203,600	$205,300	$291,600